Engaging K-12 Students in Science: Validating Satellite Imagery with GLOBE Observations

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Introduction

The University of Toledo has focused on using GLOBE student observations to validate algorithms developed for NASA satellites. We have developed a new surface skin temperature protocol, i.e. the temperature of sidewalks, parking lots, leaves, grass, bare ground as determined by the electromagnetic energy they emit. Surface temperature is at the heart of the energy cycle because it is influenced by incoming solar radiation as well as the properties of the surface and subsurface. The surface temperature protocol may be especially useful to inner-city schools with limited natural space.
In addition, we have used GLOBE snow and cloud data to validate the snow detection algorithm and cloud screening technique from the Moderate Resolution Imaging Spectroradiometer (MODIS) on the Terra satellite. Intensive student observation campaigns have been held during the last four winters that have produced a valuable dataset for this work. Through this process, K-12 teachers and students have been engaged in inquiry-based research. Through this project we engaged Jackie Kane, a teacher from St. Ursula Academy, and her student to analyze MODIS satellite imagery.

Quality Assurance; Data Entry Problems

We have spent the past year working with teachers to test potential errors in data gathering and entry that may occur and negatively affect the use of GLOBE data in research. We trained 28 teachers in a workshop during the summer of 2003 and asked them to have their students take surface temperature observations during two weeks in December 2003 and another two weeks in January and February 2004. We set up a separate website for data entry outside of the GLOBE website. This helped us have more hands-on interaction with the data, the students and the teachers which gave us first hand experience into the issues that GLOBE students and teachers will encounter with the surface temperature protocol. Of the 421 observations collected by this group, we found

that nearly half of the observations had an error of some sort. We tested the students' and teachers' abilities to convert their local time to Universal Time (UT). We had the students and teachers enter both local time and UT for the surface temperature observations. Over 68 observations of the 421, 16%, had the incorrect UT. We feel that our group of teachers was typical of teachers submitting GLOBE observations with the most frequent error being one, two and three hours but up to twelve hours in a couple of cases. In several cases the hours were subtracted from the local time instead of added. In addition, eleven schools out of 28 submitted reports with incorrect UT. Three schools had the wrong UT for every data entry however, the other eight had between one and five incorrect UT entries. Our results lead us to believe that the UT will be entered incorrectly into the GLOBE database a significant number of times.

Another problem area was the units of the observations the students submitted. Forty observations were entered in Fahrenheit instead of Celsius. We were able to identify most of these cases because 40 C is not possible in the winter in Ohio. However, there are temperatures such as ten degrees in which it is harder to tell if it was Celsius or Fahrenheit. Reporting snow depth was often submitted as cm or inches instead of mm.

Finally, we noticed incorrect observations. In one case, a teacher did not read the protocol for surface temperature observations and used his current temperature thermometer instead of the non-contact infrared thermometer (IRT) recommended by GLOBE. Another teacher in Western New York reported over 200 mm of snow pack one day and then only 3 mm the next. This drew attention because of the snowy winter in western New York and it was obvious that the snow did not melt. When contacted, the teacher revealed that the snow had drifted away. She did not know that she should measure the snow in an area in which the snow did not drift.

Validation of the MODIS Snow Product

For this project, we validated the Moderate Resolution Imaging Spectroradiometer (MODIS) snow product and cloud masking algorithms using GLOBE and SATELLITES (a K-12 program developed at the University of Toledo) student observations. The MODIS Snow Product is part of the MODIS snow and sea ice global mapping project conducted by NASA's Hydrological Services Branch at the Goddard Space Flight Center (Hall et al 1998). The study area is the lower Great Lakes region which includes the lake-effect snowbelt areas to the east of Lake Michigan and Lake Erie. Student observations were taken during intense field campaigns with the winter of 2001-2002 having very little snow and the winters of 2000-2001 and 2002-2003 having significant snow cover. The student observers are able to gather data over a large spatial area that would be difficult to obtain through other means. In addition, the students collected snow as well as cloud data near the satellite overpass time as well as snow water equivalent. Each observation site was geocoded and plotted onto the corresponding and georectified Version 4 MODIS snow product image for comparison.

Quantitative Analysis

Quantitative analysis of the Version 4 MODIS snow algorithm produced an accuracy of 93% when compared to student observations (Table 1). Cloud cover was a recurring problem, with 80% of the school observations were too cloudy to be used for the MODIS snow product validation. The Liberal Cloud Mask product, an experimental algorithm created to improve cloud cover interpretation, reduced overall accuracy to 78%. Figure 1 shows an example where the GLOBE/SATELLITES observations clearly showed an error in the MODIS snow data. The majority of errors where the MODIS algorithm identified no snow and the students observed snow occurred when there was very little snow on the ground, <10mm (Table 2). However, 16% of the errors occurred when there was greater than 50 mm of snow pack.

Table 1. Comparison of MODIS observations with Student observations of snow and no snow.

		Student Observations	
		Snow	Land (no snow)
MODIS Observations	Snow	128	26
	Land (no snow)	18	449
	Inland Water		4

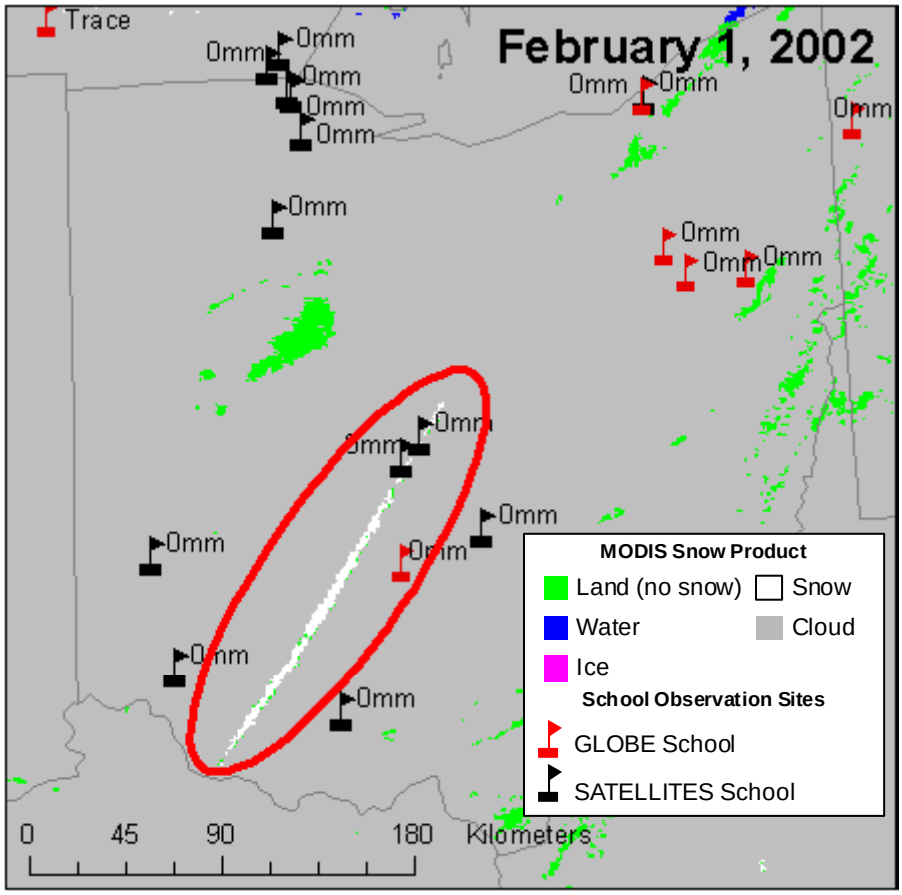

Figure 1. MODIS Snow Product erroneously detects snow in SW Ohio on February1, 2002. GLOBE schools clearly show that it was in error.

Table 2. 2000-2003 SATELLITES/GLOBE Observations listed by snow depth

Total Records	2000-2001	2001-2002	2002-2003	Total
0mm - (No Snow)	60	381	30	**471**
Trace (>10mm) snow depth	9	4	4	**17**
10 - 50mm snow depth	14	3	22	**39**
50-100mm snow depth	8	24	17	**49**
> 100mm snow depth	20	15	14	**49**
Total Records	**111**	**427**	**87**	**625**

MODIS Errors	2000-2001	2001-2002	2002-2003	Total	% Error
0mm - (No Snow)	7	7	4	**18**	**3.82%**
Trace (<10mm) snow depth	6	2	2	**10**	**58.82%**
10 - 50mm snow depth	2	0	6	**8**	**20.51%**
50-100mm snow depth	1	1	2	**4**	**8.16%**
> 100mm snow depth	2	0	2	**4**	**8.16%**
Total Records	18	10	16	**44**	**7.04%**
% Error	**16.22%**	**2.34%**	**18.39%**	**7.04%**	

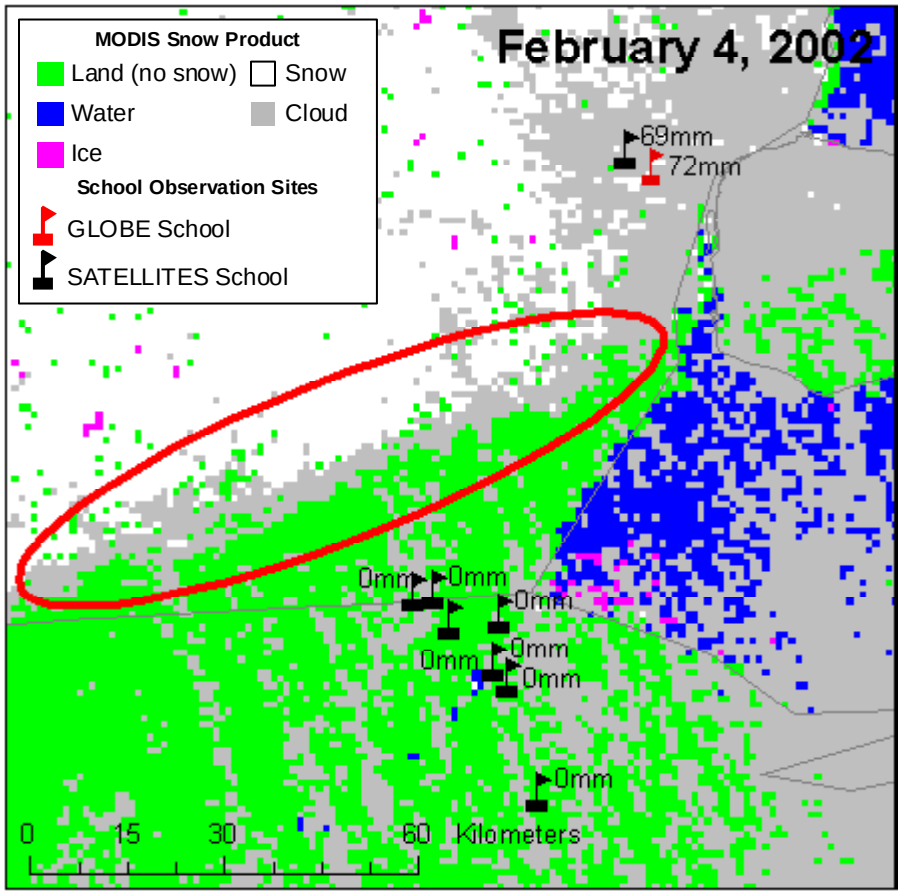

Figure 2. MODIS Snow Product Imagery from February 4, 2002. Unusual cloud formation interpreted along the boundary between snow and land is a common error that Julia Gehring identified as a potential error.

Qualitative Analysis

A tenth-grade student and her teacher at St. Ursula Academy in Toledo performed a qualitative study. They found that the snow product sometimes misidentifies clouds as snow cover, and conversely it sometimes misidentifies snow cover as clouds. Anomalies in the MODIS snow product imagery typically fell into one of three categories:

1. Frequent cloud classification by the algorithm at land-snow boundaries (Figure 2)
2. Frequent cloud classification by the algorithm at water-land boundaries.
3. Obscure snow strip classification in otherwise partly cloud-covered land.

Cloud Mask Validation

The cloud observations taken within three hours of the MODIS image generally agree with the cloud mask interpretation in the snow cover SDS. In the cases when the pixel extraction indicates clouds, 67% of the schools report overcast skies (91-100% cloud cover), 16% report broken cloud cover (51-90% cloud cover), and only 7% report clear skies (0-10% cloud cover). In conditions when the MODIS snow cover SDS indicates a classification other than cloud cover, 46% of the school observations also report clear skies (0-10% cloud cover), 11% indicate isolated cloud cover (11-25% cloud cover), 19% scattered clouds (26-50% cloud cover), while 13% report broken clouds (51-90% cloud cover) and 11% report overcast conditions (91-100% cloud cover). Surprisingly, the overall accuracy of the schools' cloud cover observations vary little within the three hour window before or after the MODIS image.

Reference

Hall, D.K., A.B. Tait, G.A. Riggs, V.V. Salomonson, with contributions from J.Y.L. Chien, A.G. Klein, October 7, 1998: "Algorithm Theoretical Basis Document (ATBD) for the MODIS Snow-, Lake Ice- and Sea Ice-Mapping Algorithms, Version 4.0."